Mineral Provinces

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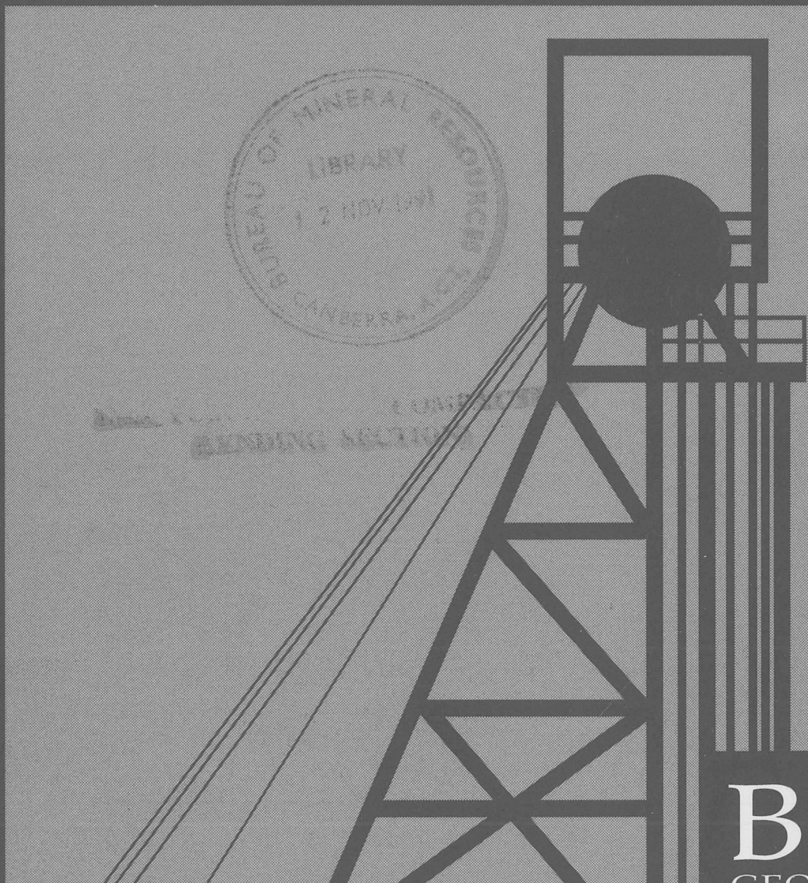
Preliminary Report on the Geology of Vaughan 1:100 000 Map Sheet (Mount Doreen 1:1250 000 Sheet), Arunta Block and Ngalia Basin, Northern Territory. Record 1991/65

AUSTRALIA



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by
D.H. Blake

MINERALS AND LAND USE PROGRAM
BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

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Preliminary Report on the Geology of Vaughan 1:100 000 Map Sheet (Mount Doreen 1:1250 000 Sheet), Arunta Block and Ngalia Basin, Northern Territory. Record 1991/65

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Geoscience for Australia's future

DEPARTMENT OF PRIMARY INDUSTRIES AND ENERGY

Minister: The Hon. Alan Griffiths

Secretary: G.L. Miller

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

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SUMMARY

The Vaughan map sheet covers parts of the early to middle Proterozoic Arunta Block and, to the south, the late Proterozoic to Carboniferous Ngalia Basin. The oldest rocks exposed, mapped as Lander Rock beds (?1880 Ma), were folded and metamorphosed to mainly upper greenschist/lower amphibolite facies before being overlain by the Reynolds Range Group (?1820 Ma), represented by Mount Thomas Quartzite and Pine Hill Formation in the far north. The Reynolds Range Group was folded into an isoclinal synclinal and metamorphosed to greenschist facies prior to emplacement of Wabudali Granite (informal new name). Intrusions south of the Reynolds Range Group include bodies of xenolithic granite, gneissic granite, voluminous younger coarsely porphyritic granite (?1500 Ma), metadolerite dykes, and lamprophyre. These predate the Ngalia Basin succession, the main units of which are the Vaughan Springs Quartzite and Treuer Member at the base and the Mount Eclipse Sandstone at the top. The Ngalia Basin succession was affected by folding, faulting, and thrusting during the 400-300 Ma-old Alice Springs Orogeny. Faults marked by ridge-forming quartz veins postdate granite but may predate the Ngalia Basin succession. Tungsten and minor copper mineralisation occurs in Wabudali Granite at Wilsons Find in the far north and uranium mineralisation is present in Mount Eclipse Sandstone at Bigrlyi prospect near the northern margin of the Ngalia Basin in the east.

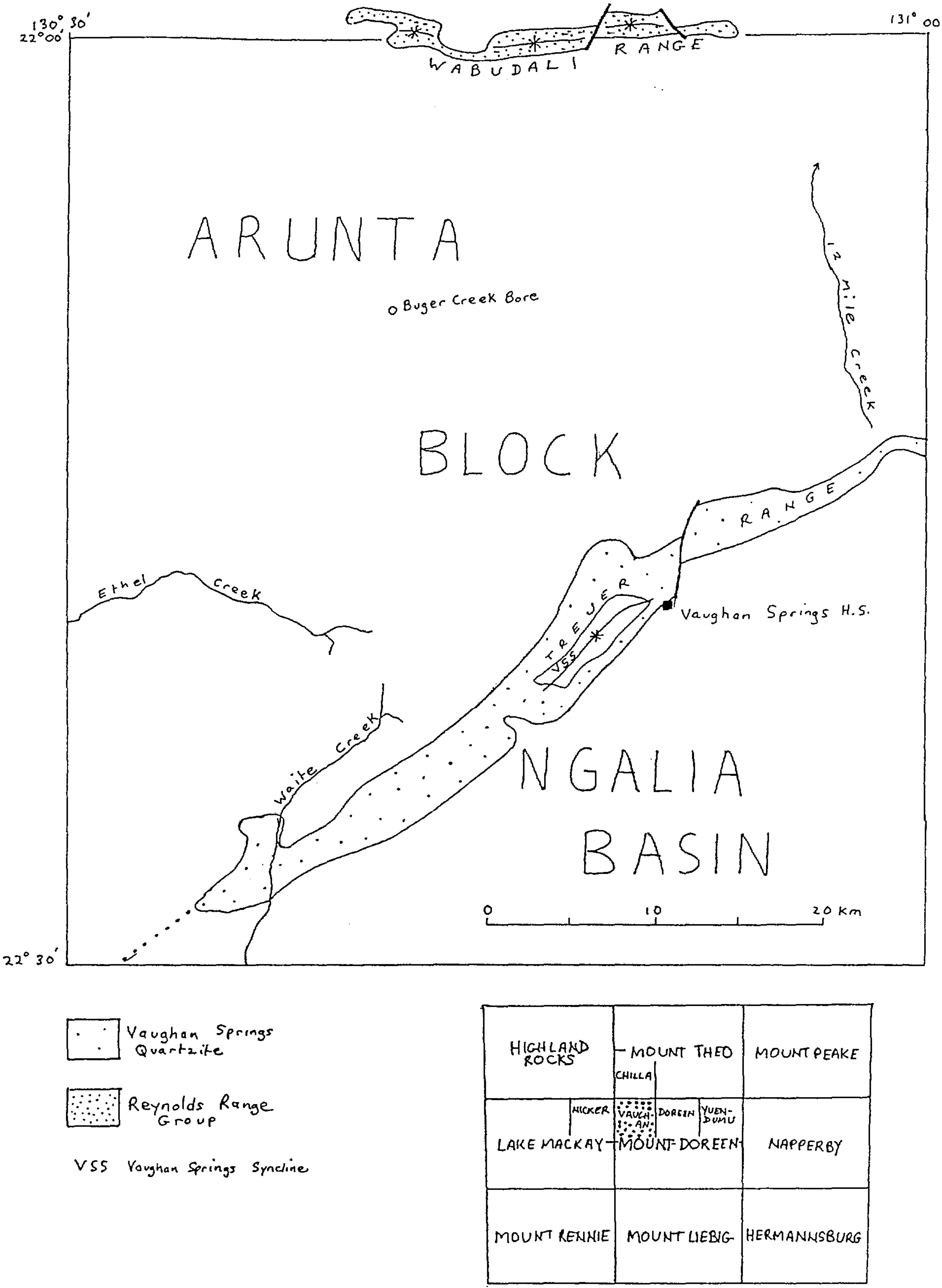

Figure 1. Locality map, Vaughan 1:100 000 sheet area.

INTRODUCTION

The Vaughan 1:100 000 map sheet is bounded by latitudes 22°00' and 22°30' and longitudes 135°30' and 131°00', and occupies the northwestern part of Mount Doreen 1:250 000 sheet area (Figure 1). A detailed reconnaissance survey of the geology of most of Vaughan and small parts of the adjoing Lake Mackay and Mount Theo 1:250 000 sheet areas to the west and north (Nicker and Chilla 1:100 000 sheets, respectively), was carried out by the author in June-July 1990, with some additional observations from C.Edgoose (NTGS); the survey should be completed in July-August 1991. NTGS geologists (C.Edgoose and D.N.Young) mapped the Doreen and Yuendumu 1:100 000 map sheets to the east of Vaughan in 1990. The area mapped by BMR and NTGS during 1990 covers parts of the early to middle Proterozoic Arunta Block and, in the south, part of the late Proterozoic to Palaeozoic Ngalia Basin.

The mapping was carried out as part of the Kimberley-Arunta Project, under the National Geoscience Mapping Accord. The aims of the project are: to determine, through systematic mapping, the nature, timing, and distribution of significant geological events in and between the west Arunta, The Granites-Tanami, and east Kimberley areas of the North Australian Craton; to determine the extent of prospective basement beneath thin cover; to describe styles of mineralisation that can be used as predictive exploration models; and to provide geological and mineral resource information necessary for land use decisions. The Kimberley-Arunta project was started in 1990 and is due to be completed in 1995.

The only permanent habitation in the Vaughan map sheet is Vaughan Springs homestead on Mount Doreen station, which is connected to the Tanami Road to the east by graded roads and tracks. The climate is semi-arid tropical, with an average annual rainfall of less than 250 mm. Spinifex and mulga dominate the vegetation. Ridges, rounded hills and tors of Precambrian rocks are separated by plains covered with Quaternary sediments. Sand dunes are present in the south. The local relief is less than 100 m except in parts of the Wabudali Range in the far north and the Treuer Range of central Vaughan. The main drainage channels are those of the north-flowing 12-mile Creek in the east, the west-flowing Ethel Creek in the west, and the southwest-flowing Waite Creek in the southwest.

The Mount Doreen and Lake Mackay 1:250 000 sheet areas were included in the regional geological mapping of the Ngalia Basin by BMR between 1967 and 1969 (Wells, 1972; Nicholas, 1972; Wells & Moss, 1983). Both sheet areas were covered by an airborne magnetic and radiometric survey, 1.5 km line spacing, in 1976. The Mount Theo 1:250 000 sheet was geologically mapped by BMR in 1972 (Stewart, 1976), but has yet to be covered by airborne geophysics.

Map production

The Vaughan map sheet and adjoining part of Lake Mackay were mapped using vertical colour aerial photographs at about 1:25 000 scale taken in 1972. The southernmost part of Mount Theo to the north was mapped using RC9 black and white photography flown in 1971, nominal scale 1:80 000. Field data and photo-interpreted geological boundaries were plotted onto transparent overlays on the aerial photographs and then compiled on photoscale topographic bases. The resulting compilation sheets were digitised and entered into an ARC/INFO GIS (Geographic Information System), copies of which can be purchased from BMR.

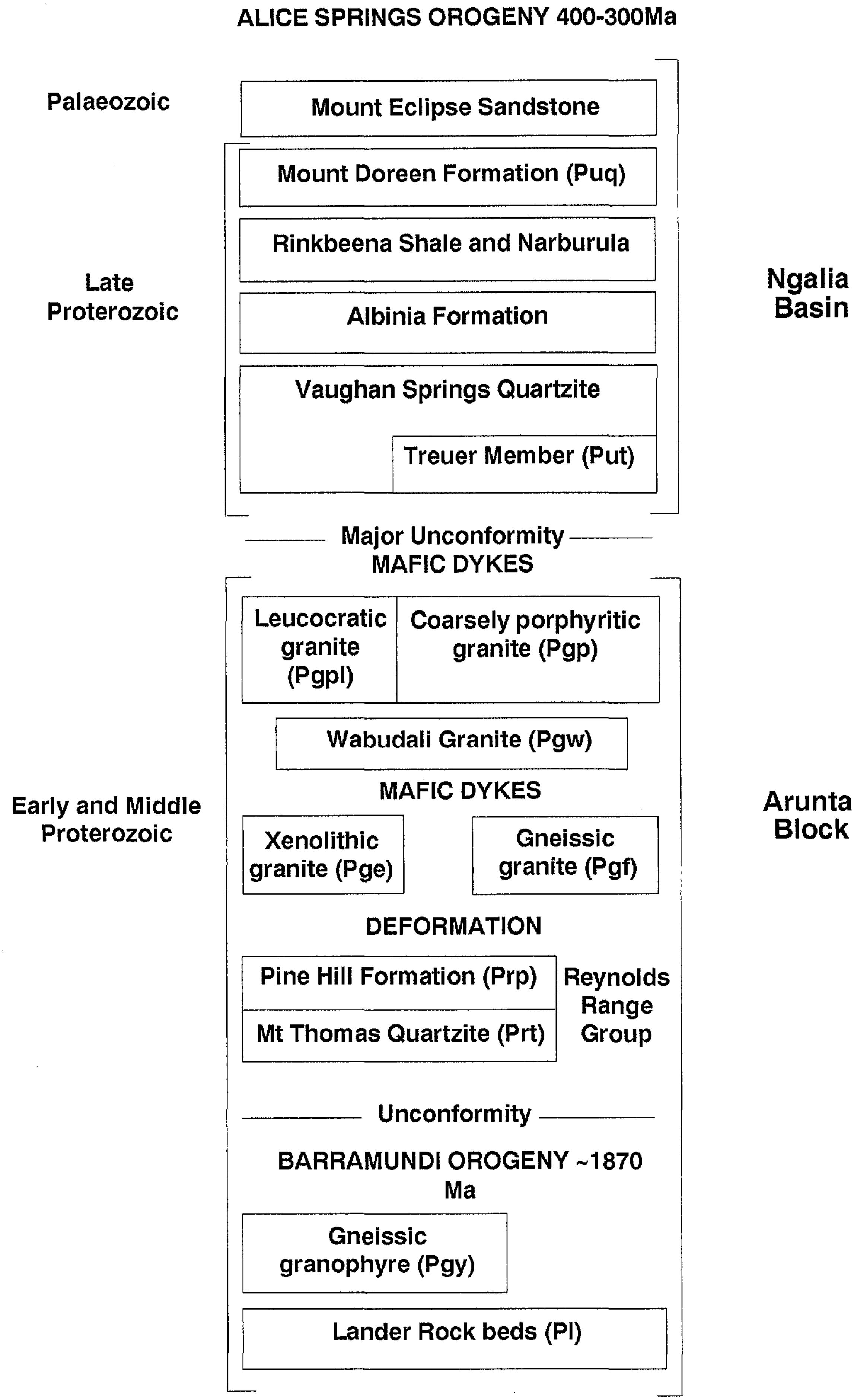

Figure 2. Stratigraphic scheme for Vaughan 1:100 000 sheet area.

OUTLINE OF GEOLOGY

The stratigraphy, intrusive activity, and deformational history of the Vaughan area are summarised in Figure 2.

The oldest rocks exposed, assigned to the Lander Rock beds, are greywacke, siltstone, sandstone, and minor mafic and felsic volcanics which have been regionally metamorphosed mainly to upper greenschist or lower amphibolite facies, although higher grade migmatitic rocks are present locally. In the far north the Lander Rock beds are intruded by gneissic granophyre and younger Wabudali Granite (new name), and are overlain probably unconformably by Reynolds Range Group. This group, which comprises quartz sandstone of the Mount Thomas Quartzite and sandstone, siltstone, carbonates, and basalt of the Pine Hill Formation, was folded into a major upright isoclinal syncline and metamorphosed to probably upper greenschist facies before being intrused by Wabudali Granite. To the south the Lander Rock beds are intruded by gneissic granite, xenolithic granite, voluminous coarsely porphyritic granite, leucogranite, and undivided granite. The granites postdate the main folding of the Lander Rock beds, but predate some mafic dykes, the youngest igneous in the area, and also faults marked by ridge-forming quartz veins.

The Arunta Block is overlain to the south by the Ngalia Basin succession, represented mainly the late Proterozoic Vaughan Springs Quartzite, the basal part of which is the Treuer Member, and the Devonian to Carboniferous Mount Eclipse Sandstone crops out mainly in the central part of the Ngalia Basin. The Ngalia Basin succession was affected by folding, faulting, and thrusting during the Alice Springs Orogeny, 400-300 Ma ago. Since the end of the Alice Springs Orogeny the area has been part of a tectonically stable craton subjected to almost continuous subaerial erosion, and now consists of residual hills and ridges rising above extensive plains covered by superficial Cainozoic sediments.

ROCK UNITS OF THE ARUNTA BLOCK

Lander Rock beds

Named and defined in Stewart & others (1980).

Map symbols. Plt, Pltb, Pld, Pls, Plm.

Distribution. Northern and western parts of the mapped area, north of the Ngalia Basin.

Thickness. Probably several thousand metres; base not exposed, and no underlying unit known.

Topography. Forms low ridges and hills and undulating terrain.

Lithology. Turbiditic greywacke and siltstone, sandstone, basalt, felsic porphyry, and migmatite metamorphosed to schist, quartzite, amphibolite, and migmatite; cut by numerous quartz veins, some of which predate deformation.

Plt. Turbiditic beds: metagreywacke and metasiltstone, thick to thin-bedded, generally schistose, consist mainly of biotite, muscovite, quartz, and alkali feldspar; subordinate variably feldspathic and micaceous quartzite; minor quartz-tourmaline rock and amphibolitic metabasalt; rare calc-silcate bands. Porphyroblasts of andalusite, in places more than 3 cm long, muscovite, and tourmaline, and less commonly fibrolitic sillimanite, garnet and ?cordierite, occur near intrusive granite contacts .

Pltb. Turbiditic beds, as in Plt, with interlayered and locally cross-cutting amphibolite bands, some of which represent amygdaloidal lava flows.

Pls. Thinly bedded quartzite, micaceous quartzite, feldspathic quartzite, and quartz-muscovite schist; cherty siltstone; minor biotite-muscovite schist and gossany ironstone. In west (Nicker 1:100 000 Sheet area), centred at GR 517270, this unit includes a lens up to 500 m thick of felsic volcanics - small quartz and feldspar phenocrysts in a fine-grained schistose groundmass.

Pld. Body of metadolerite and metagabbro, centred at GR 745435, consisting mainly of pale amphibole (some with cores of remnant pyroxene) and partly recrystallised plagioclase; minor pods and veins of anothosite and small irregular patches of carbonate (filling vesicles?); weak to strong east-west trending subvertical foliation. Interbanding of fine-grained amphibolite (mafic tuff?) and metasandstone and metasiltstone at northern margin indicates that the unit could be extrusive rather than intrusive, in spite of relatively coarse grain-size. Southern margin is cut by granitic veins.

Plm. Migmatitic metasediments - irregularly folded banded gneisses with leucosomes; consist predominantly of quartz, muscovite (some of which occurs as fine-grained aggregates possibly representing altered sillimanite and/or andalusite and/or feldspar), biotite, and porphyroblastic tourmaline.

Deformation and metamorphism. Tightly folded on outcrop scale, mainly about upright east-west-striking axial planes. Axial planar cleavage/schistosity well developed, especially in turbiditic beds; minor folds, crenulations, and bedding-cleavage intersection lineations common; quartzite beds locally boudinaged. Regionally metamorphosed mainly to upper greenschist or lower amphibolite facies; retrogressed from higher grade (up to granulite facies?) where migmatitic. Affected by contact metamorphism near granite intrusions, with developement of porphyroblastic andalusite, muscovite, tourmaline, and garnet, fibrolitic sillimanite, and possible cordierite (pseudomorphed); some andalusite and garnet porphyroblasts contain folded inclusion trails.

Mineralisation. None known in Vaughan; host for some Cu-bearing quartz vein deposits to east.

Relationships. Base not seen. Overlain, probably unconformably, by Mount Thomas Quartzite of Reynolds Range Group. Intruded by mafic dykes, gneissic granophyre, Wabudali Granite, and unnamed granites; cut by pegmatite, quartz-tourmaline and quartz veins.

Age. May be similar to that of the lithologically similar Warramunga Group of the Tennant Creek Inlier and Halls Creek Group of East Kimberley, hence about 1890 Ma.

Correlatives. Part or all of the Tanami Complex of The Granites-Tanami region to north, Halls Creek Group to northwest, and Warramunga Group to northeast (e.g., Blake, 1978).

Remarks. Probably affected by three major deformations (BMR, 1990): 1, the 1870 Ma Barramundi Orogeny, 2, sometime between deposition of the Reynolds Range Group (1820-1800 Ma?) and intrusion of Wabudali Granite (1500 Ma?), and 3, the Alice Springs Orogeny (400-300 Ma); all three deformations appear to have been dominated by east-west trending structures, so were essentially co-axial. No stratigraphic sequence mapped within Lander Rock beds, so relative ages of subunits not known. Subunit Plm in northwest, mainly in Nicker 1:100 000 sheet area (Lake Mackay), could represent basement underlying Lander Rock beds: inclusions of both migmatite and bedded Lander Rock metasediments are present in xenolithic granite to southeast. Subunit Pls is separated from subunit Plt to north by major fault; it could be a correlative of Patmungala beds in adjacent Doreen map area to east, dated at about 1830 Ma (C.Edgoose, personal communication, 1991), and hence possibly younger than rest of Lander Rock beds. Shown as unnamed Precambrian schist, amphibolite, quartzite, and gneiss on Mount Doreen map of Wells (1972) and Lake Mackay map of Nicholas (1972) and as Lander Rock beds on Mount Theo map of Stewart (1976).

Gneissic granophyre

Map Symbol. Pgy.

Distribution. Crops out on the north sides of the Wabudali Range and a smaller range along strike to the west, in Chilla 1:100 000 sheet (Mount Theo).

Topography. Generally recessive, but forms some low hills and rocky mounds.

Lithology. Dark greyish, fine-grained gneiss with small quartz and feldspar augen. In thin sections the augen are seen to be deformed phenocrysts lying in a fine-grained micrographic (granophyric) groundmass with biotite and muscovite.

Deformation and metamorphism. Gneissic to schistose, with east-west trending subvertical foliation/cleavage; steeply plunging lineation (mineral elongation) present in places. Primary igneous minerals highly strained, especially quartz; primary biotite partly altered to chlorite.

Relationships. Contacts poorly exposed. Inferred to intrude Lander Rock beds and to be overlain by (as more deformed than) south-dipping Mount Thomas Quartzite, the basal formation of the Reynolds Range Group. Intruded by mafic dykes, Wabaduli Granite, and pegmatite veins related to this granite.

Age. ?1880 Ma. As the granophyre is strongly foliated, even where overlain by little deformed Mount Thomas Quartzite, it may have been deformed, like the Lander Rock beds, before deposition of the Reynolds Range Group.

Remarks. A high-level, possibly subvolcanic, felsic intrusive rock. Not distinguished from unnamed granite on Mount Theo map (Stewart, 1976).

REYNOLDS RANGE GROUP

Named and defined in Stewart & others (1980)

Map symbol. Pr.

Constituent formations. Mount Thomas Quartzite (at base), Pine Hill Formation.

Distribution. Restricted in Vaughan to the Wabudali Range, on northern edge of the sheet. Continues along strike to west-northwest, in southwest Mount Theo and probably southeast Highland Rocks 1:250 000 sheet areas. Main outcrop area is in the Reynolds Range, Napperby 1:250 000 sheet, to east.

Thickness. 1000 m.

Topography. Forms the Wabudali Range.

General lithology. Quartz sandstone, lithic/feldspathic sandstone, subgreywacke, siltstone, carbonates, basalt.

Deformation and metamorphism. Folded into a major, upright to slightly overturned (to the south), near-isoclinal syncline trending east-west; axial planar cleavage/schistosity generally prominent; locally mylonitic. Regional metamorphism probably upper greenschist facies; also affected by contact metamorphism.

Relationships. Overlies, probably unconformably, Lander Rock beds and gneissic granophyre; intruded by Wabudali Granite, pegmatite veins, and rare metadolerite dykes.

Correlatives. Probably a correlative of the Hatches Creek Group of the Davenport province to northeast (e.g., Stewart & others, 1984; Dirks, 1990). Other possible correlatives are Patmungla beds in Doreen 1:100 000 to east (C.Edgoose, personal communication, 1991), Supplejack Sandstone, Pargee Sandstone and Mount Winnecke Formation in The Granites-Tanami region to northwest (Blake, 1978; Stewart & others, 1984), and Speewah and Kimberley Groups of the Kimberley region further to the northwest.

Age. Between about 1830 and 1800 Ma, if correlated with Hatches Creek Group (R.W.Page, personal communication, 1990).
Mineralisation. None known.
Remarks. Probably deposited on shallow marine shelf (Dirks, 1990) Previously mapped as unnamed Precambrian schist and quartzite in Mount Doreen (Wells, 1972); shown as Reynolds Range Group on Mount Theo map of Stewart (1976).

Mount Thomas Quartzite

Named and defined in Stewart & others (1980).
Map symbol. Prt.
Distribution. Wabudali Range.
Topography. Ridge-forming.
Thickness. 150-400 m.
Lithology. Quartzite (= metamorphosed quartz sandstone): mainly medium-grained, medium to thick bedded; cross-bedding, including prolapsed and large-scale high-angle types, commonly evident; locally conglomeratic at base, with pebbles and cobbles of quartzite and vein quartz. Partly mylonitic (along bedding- parallel faults?), thin-bedded to platy, with very low-angle cross-bedding and flattened pebbles, on southern side of Wabudali Range.
Deformation and metamorphism. Steeply dipping to overturned on limbs of major east-west trending syncline; highly compressed and mylonitic along much of southern limb. Variably recrystallised.
Relationships. Overlies Lander Rock beds and gneissic granophyre: the contact, where not a fault, is probably an unconformity, as the formation appears to post-date mesoscale folding in nearby Lander Rock beds south of the Wabudali Range and is much less deformed than immediately underlying gneissic granophyre on the north side of this range. Intruded by Wabudali Granite, pegmatite veins, and rare mafic dykes.

Pine Hill Formation

Named and defined in Stewart & others (1980).
Map symbols. Prp, Prpc.
Distribution. Wabudali Range.
Topography. Forms alternating strike ridges and valleys; less resistant to erosion than Mount Thomas Quartzite.
Thickness. Up to 600 m; top not preserved.
Lithology. Ridge-forming metasandstone and recessive metasiltstone (Prp) at top and bottom, separated by central band of carbonates and metabasalt (Prpc).
Sandstone: friable to silicified; iron-stained to bleached; quartzose to sericitic (muddy?) and also possibly slightly calcareous (pitted weathered surfaces); medium to fine-grained; thick-bedded to laminated; rather rare cross-bedding and slump structures (including prolapsed bedding); generally shows subvertical east-west trending cleavage. **Siltstone:** medium to pale grey; schistose to phyllitic; thinly bedded to laminated; interbedded with sandstone; micaceous; andalusite porphyroblasts common close to Wabudali Granite.
Carbonates: predominate in middle of formation; include calcareous sandstone and siltstone, grey limestone/marble, epidotic calc-silicate rocks, sideritic? ironstone, and ochreous dolomite?; some slump bedding; minor folds developed in axial zone of major syncline.
Metabasalt: 0 to more than 30 m thick in middle of formation; amygdaloidal, especially near margins, with quartz, carbonate and some sulphides in amygdales; flow-margin

breccias present in places; overlying and underlying sedimentary rocks commonly contain fine-grained basaltic debris.
Deformation and metamorphism. Exposed in axis of major east-west syncline, which in west plunges at around 20 to east; east- plunging small-scale folds in carbonates at western fold closure; shows well developed axial planar cleavage. Metamorphic muscovite and biotite in metasiltstone and green amphibole and sodic plagioclase in metabasalt indicate upper greenschist (or lower amphibolite?) facies; andalusite porphyroblasts probably result of contact metamorphism.
Relationships. Conformable on Mount Thomas Quartzite. Intruded by Wabudali Granite.

Gneissic granite

Map symbol. Pgf.
Distribution. Northeast quadrant of Vaughan, in general vicinity of Carrington Bore and to west.
Topography. Forms scattered small kopje-like tors on sand plain.
Lithology. Felsic gneiss: strongly foliated, medium to fine-grained, biotite and muscovite-biotite granite: generally homogeneous and even-grained, but sparse feldspar phenocrysts up to 1 cm across present in places; commonly contains small fine-grained xenoliths of biotite tonalite. Gneissic granite at GR 835467 contains subhedral andalusite.
Deformation and metamorphism. Stong foliation parallels that in adjacent Lander Rock beds. Primary quartz is highly strained; secondary muscovite, chlorite and epidote commonly present.
Relationships. Intrudes Lander Rock beds; intruded by foliated mafic dykes and probably coarsely porphyritic granite.
Age. ?1880. Foliated and metamorphosed with adjacent Lander Rock beds.
Remarks. Mesozonal or epizonal, as relatively fine-grained. Shown as undivided Precambrian granite on Mount Doreen map of Wells (1972).

Xenolithic granite

Map symbol. Pge.
Distribution. Northern central Vaughan, south of Buger Creek Bore.
Type area. Tor at GR 713430.
Topography. Forms mainly low tors, gently undulating terrain, and partly concealed spheroidal boulders.
Lithology. Grey medium-grained biotite and muscovite-biotite granite - CI up to 30, typically with abundant xenoliths of bedded metasedimentary rocks, swirly migmatite, fine-grained biotite-rich rocks, and vein quartz (all derived from Lander Rock beds?); small feldspar phenocrysts (cm) present in places; minor pegmatite, aplite, and microgranite.
Deformation and metamorphism. Weakly to strongly foliated; biotite is commonly recrystallised and quartz is highly strained.
Relationships. Intrudes Lander Rock beds; intruded by mafic dykes and coarsely porphyritic granite (Pgp).
Age. ?1800 Ma.
Remarks. Postdates main schistosity of Lander Rock beds, as contains disoriented blocks of schist, but predates Pgp. Shown as undivided Precambrian granite on Mount Doreen map of Wells (1972).

Wabudali Granite

New name, not yet formalised; named after the Wabudali Range, on northern margin of Vaughan 1:100 000 Sheet.
Distribution. Northernmost part of Vaughan, and extending north into Chilla and west into Nicker 1:100 000 sheet areas.
Type area. Western end of Wabudali Range, in Chilla, where the granite is well exposed as tors and pavements, and is seen to intrude Reynolds Range Group.
Topography. Generally recessive, as mostly friable, but forms some low tors, bornhardts, and pavements, and also rock benches along north side of Wabudali Range. Cut by some ridge-forming quartz veins (quartz-filled faults).
Lithology. Pale medium to coarse-grained biotite-muscovite granite; colour index typically around 5; commonly contains abundant white tabular Oligoclase phenocrysts 1-3 cm long which in some places show a pronounced swirly flow alignment; subordinate even-grained phases and minor aplite and pegmatite. Quartz-feldspar pegmatite veins, some containing tourmaline, common in adjacent country rocks.
Deformation and metamorphism. Mostly appears undeformed, but is locally strongly foliated and mylonitic, mainly along faults marked by ridge-forming quartz veins; these faults may be related to the Alice Springs Orogeny. Thin-sections show that primary quartz is invariably highly strained.
Mineralisation. Host to tungsten and copper mineralisation at Wilsons Find, at western end of Wabudali Range in Chilla (GR 715685): wolframite, malachite and chryscolla occur with tourmaline in southeast-trending quartz-rich greisen veins up to 2m wide.
Relationships. Intrudes Lander Rock beds, gneissic granophyre, and Reynolds Range Group - roof and side contacts are well exposed along the Wabudali Range, and blocks of quartzite several metres across occur in the granite at the western end of this range.
Age. ?1750 Ma. Postdates folding of the Reynolds Range Group in the Wabudali Range and predates faulting probably related to the Alice Springs Orogeny.
Correlations. None known.
Remarks. Andalusite porphyroblasts are present in adjacent contact metamorphosed pelitic country rocks, so the granite is probably mesozonal, emplaced at a depth of several kilometres. Shown as undivided Precambrian granite on Mount Doreen and Mount Theo 1st edition maps (Wells, 1972; Stewart, 1976).

Coarsely porphyritic granite

Map symbol. Pgp.
Distribution. Abundant exposures north of the Ngalia Basin, extending north to within about 6 km of the Wabudali Range.
Type area. Tors and bornhardts in the vicinity of the prominent peak in Vaughan known as 'Woman dreaming', at GR 898431.
Topography. Tors, bornhardts, rock pavements and spheroidal boulders.
Lithology. Coarsely porphyritic biotite granite; minor non-porphyritic phases, aplite, heterogeneous microgranite.
Porphyritic biotite granite: characterised by generally abundant, pale pinkish, equidimensional, poikilitic phenocrysts of alkali feldspar (microcline), 1 cm and in places up to 10 cm across, and smaller phenocrysts of equant quartz and white tabular sodic plagioclase in a fine to coarse-grained, pale pinkish to greyish groundmass of mainly quartz, feldspar, and biotite (commonly in small clots); some muscovite, partly secondary,

is commonly present, as is secondary chlorite after biotite; dark fine-grained xenoliths of biotite tonalite present in places.
Heterogeneous microgranite: pale to dark grey biotite microgranite with irregularly distributed microcline and plagioclase phenocrysts similar to those in adjacent granite; streakily banded in places; forms irregular vein-like bodies a few centimeters to over a metre thick near GR 775570.
Deformation and metamorphism. Not foliated, except near faults, but quartz invariably highly strained; secondary muscovite and chlorite may be related to low grade regional metamorphism during the Alice Springs Orogeny.
Relationships. Intrudes Lander Rock beds and some granite (Pge and Pgf) and mafic dykes; not seen in contact with Reynolds Range Group or Wabudali Granite (Pgw); overlain by Vaughan Springs Quartzite; cut by mafic dykes, lamprophyre (at GR 850453), and quartz-filled faults.
Age. ?1500 Ma. Predates Vaughan Springs Quartzite and postdates folding of Reynolds Range Group.
Correlations. Similar coarsely porphyritic granite exposed in Doreen and Yuendumu 1:100 000 sheet areas to east.
Mineralisation. None known.
Remarks. Probably mesozonal to epizonal intrusions. Shown as undivided Precambrian granite on Mount Doreen map of Wells (1972).

Leucocratic granite

Probably a variant of coarsely porphyritic granite.
Map symbol. Pgpl.
Distribution. N side of the Treuer Range in eastern Vaughan.
Type area. N side of Treuer Range, near GR 031419.
Topography. Exposed in creeks and on footslopes.
Lithology. Medium to coarse leucogranite; typically friable and bleached; widely scattered feldspar phenocrysts up to 2 cm across present in places, as are small xenoliths.
Deformation and metamorphism. Does not appear to be deformed or metamorphosed.
Relationships. Intruded by mafic dyke in 12 Mile Creek; faulted against Vaughan Springs Quartzite to south; overlain by Vaughan Springs Quartzite (Treuer Member) to east (in Doreen 1:100 000 sheet area).
Age. ?1500 Ma. Predates Ngalia Basin sequence, and probably similar in age to Pgp.

Unassigned granite

Includes all granite of uncertain affinities.
Map symbol. Pg.
Distribution. Several outcrops north of Ngalia Basin.
Topography. Small tors, spheroidal boulders.
Remarks. Main body in northwest, centred at GR 670470: medium-grained muscovite granite with scattered feldspar phenocrysts; intrudes Lander Rock beds and cut by northeast-trending metadolerite dykes; postdates main schistosity in Lander Rock beds.

Mafic dykes

Map symbol. Dyke symbol, dl.
Distribution. Arunta Block north of Ngalia Basin.
Topography. Recessive; poorly exposed. Some dykes show up as dark lines on aerial photographs, mainly trending between northeast and east.

Lithology. Dark, fine-grained **metadolerite:** non-foliated to foliated; samples thin-sectioned contain metamorphic sodic plagioclase and green amphibole, but most have igneous textures partly preserved, suggestive of upper greenschist facies metamorphism, and some contain remnants of primary pyroxene.
Lamprophyre: dyke 20 cm thick at GR 850453; consists of euhedral biotite and augite in groundmass of altered glass.
Relationships. Intrude Lander Rock beds, gneissic granophyre, Reynolds Range Group, gneissic granite, xenolithic granite, and coarsely porphyritic granite; also cut by coarsely porphyritic granite (e.g., at GR 757408). Dyke of non-foliated metadolerite cuts gneissic granophyre at GR 726685. Lamprophyre at GR 850453 cuts coarsely porphyritic granite.
Age. At least two ages apparent, as some dykes predate and others postdate emplacement of coarsely porphyritic granite. The younger dykes may include equivalents of the 900 Ma old Stuart Dyke Swarm to the southeast (Black & others, 1980).
Remarks. Most dykes seen are less than 5 m thick.

Siliceous breccia

Map symbol. Ps.
Distribution. Hillock at GR 795287, less than 1.2 km from Ngalia Basin to east.
Description. Recrystallised siliceous breccia: small angular fragments of quartz in fine-grained iron-stained matrix; may represent silcrete or a silicified palaeoregolith developed prior to deposition of the Ngalai Basin succession and subsequently metamorphosed (during the Alice Springs Orogeny).

NGALIA BASIN SUCCESSION

Vaughan Springs Quartzite

Named and defined by Wells & Moss (1983).
Map Symbol. Puv (undivided), Put (Treuer Member).
Distribution. Northern margin of Ngalia Basin, central and southern part of sheet area (Wells, 1972).
Topography. Puv is prominent ridge-forming unit; forms the higher parts of the Treuer Range. Put forms lower strike ridges and hills.
Thickness. About 1750 m in type section, 6 km west of Vaughan Springs homestead.
Lithology. Quartz sandstone (Puv): silicified to friable; mainly medium-grained, medium to thick bedded, cross-bedded; also ripple marks.
Deformation and metamorphism. Folded about axial planes subparallel to northern margin of Ngalia Basin; main fold is the Vaughan Springs Syncline west of Vaughan Springs homestead. Variably recrystallised.
Relationships. Puv conformably overlies Treuer Member around margins of the Vaughan Springs Syncline and along north side of Treuer Range to east; it is locally faulted against porphyritic and non-porphyritic granite. Put overlies granite nonconformably.
Age and correlations. Minimum age of 1280 Ma indicated from Rb-Sr and K-Ar measurements on glauconite from Treuer Member (Cooper & others, 1971), but the formation is correlated with ?850 Ma-old Heavitree Quartzite of the Amadeus Basin (e.g., Wells & Moss, 1983); is also correlated with basal formations of the Redcliff Pound Group in the Birrindudu Basin of The Granites-Tanami region (Blake, 1978).

Treuer Member (of Vaughan Springs Quartzite).

Named and defined by Wells & Moss (1983).
Map symbol. Put.
Distribution. Northern margin of Ngalia Basin (Wells, 1972); forms basal part of Vaughan Springs Quartzite.
Topography. Narrow strike ridges and valleys.
Thickness. Up to 500 m.
Lithology. Quartz sandstone, micaceous sandstone, siltstone, claystone; medium to thin-bedded; sandstones commonly cross-bedded; also glauconitic sandstone (none identified in 1990).
Relationships, age, and correlations. See Vaughan Springs Quartzite above.

Albinia Formation

Named and defined by Wells & Moss (1983); not examined in 1990 - see Wells & Moss (1983) for details.
Distribution. Appears to be largely confined to Vaughan Springs Syncline; not seen in 1990, and not shown on map.
Thickness. Probably less than 500 m.
Lithology. Siltstone, dolomitic siltstone, shale, pale grey to black foetid stromotalitic dolomite, white to black chert.
Relationships, correlations, and age. Overlies Vaughan Springs Quartzite possibly disconformably; unconformably overlain by Mount Doreen Formation. Correlated with Bitter Springs Formation of Amadeus Basin, so slightly younger than Heavitree Quartzite.

Naburula Formation

Named and defined by Wells & Moss (1983), who suggest probable presence, thickness unknown, in the Vaughan Springs Syncline, unconformable on Vaughan Springs Quartzite and Albinia Formation and overlain unconformably by Mount Doreen Formation. Not seen in 1990, and not shown on map. Consists predominantly of dark grey to black shale and minor siltstone, grey-green and brown dolomite, and basal diamictite, and is a correlative of the late Proterozoic Areyonga Formation in the Amadeus Basin (Wells & Moss, 1983).

Rinkbeena Shale

Named and defined by Wells & Moss (1983), who suggest possible presence, thickness unknown, underlying Mount Doreen Formation in the Vaughan Springs Syncline. Not seen in 1990, and not shown on map. Consists of green shale and subordinate siltstone (Wells & Moss, 1983).

Mount Doreen Formation

Map symbol. Puq.
Distribution. Vaughan Springs Syncline.
Remarks. Not seen in 1990. As described by Wells (1972) and Wells & Moss (1983), consists of diamictite and subordinate dolomite and shale, may be up to 100 m thick in the Vaughan Springs Syncline and other parts of the Treuer Range, is unconformable on Vaughan Springs Quartzite and Albinia Formation, is overlain unconformably by Mount Eclipse Sandstone, and is correlated with youngest Proterozoic glacial sequence in the Amadeus Basin.

Mount Eclipse Sandstone

Named and defined by Wells & Moss (1983).
Map symbol. Pzt.
Distribution. Treuer Range (in centre of Vaughan Springs Syncline) and to south and east (Wells, 1972).
Topography. Generally recessive in Vaughan, but forms some low strike ridges and cuestas.
Thickness. Probably 1000 m.
Lithology. Arkosic silicified to friable sandstone and conglomeratic sandstone, subordinate siltstone; thin to thick-bedded, cross-bedded.
Deformation and metamorphism. Steeply dipping to flat-lying. Does not appear to be regionally metamorphosed.
Age. Plant fossils and spores indicate late Devonian to late Carboniferous age (Wells & Moss, 1983).
Correlations. Correlated with Pertnjara Group of the Amadeus Basin (Wells & Moss, 1983).

CAINOZOIC

The Cainozoic units mapped in Vaughan are based largely on airphoto interpretation using vegetation and geomorphic criteria. Boundaries between units range from sharp and well defined to gradational and highly diffuse, and in many cases are somewhat arbitrary. Many of the areas shown as a single unit are compound in that they consist of two or more types of sediment; for example, an area shown as aeolian sand (Qs) may contain unmapped inclusions of residual sand and silt (Qr) and alluvial sand and silt (Qa).

Laterite

Map symbol. Tl.
Description. Ferruginous cappings on low mounds, mainly within the Ngalia Basin.

Silcrete

Description. Angular fragments of quartz in amorphous siliceous matrix; occurs as small patches generally too small to show at map scale; appears to be developed mainly on granite.

Poorly consolidated gravel and sand

Map symbol. Czc.
Description. Colluvial and fluvial detritus forming inactive fans; probably mainly Tertiary rather than Quaternary.

Calcrete

Map symbol. Czk.
Description. Inorganic limestone in north formed by evaporation of groundwater; may be partly Tertiary and partly Quaternary.

Granitic sand

Map symbol. Qfg.
Description. Granitic sand/disaggregated granite forming undulating terrain in vicinity of Waite Creek, in west; merges into Pgp, Qr and Qs.

Lag gravel

Map symbol. Qg.
Description. Residual rubble, consisting largely of vein quartz, on low mounds and flanking low hills; forms thin veneer (?less than 1 m thick) on bedrock - which is mainly Lander Rock beds.

Sand and gravel on active fans

Map symbol. Qc.
Description. Unconsolidated sand and gravel on fans flanking ridges of sandstone and vein quartz.

Sheet-wash sand and silt ("red earth")

Map symbol. Qr.
Description. Sheet-wash deposits of unconsolidated sand and silt on low rises (interfluves) between drainage lines; characteristic airphoto pattern of dark-toned mulga forming closely spaced, irregularly arcuate strips and patches, convex down slope; merges into Qs.

Aeolian sand

Map symbol. Qs.
Description. Unconsolidated sand, largely aeolian, covering flat plains that are slightly higher than adjacent drainage depressions; includes sand dune country in the south and south east; merges into Qr and Qa.

Lacustrine silt, clay

Map symbol. Qp.
Description. Fine sediment and possibly some evaporites deposited in claypans; unit includes groups of closely spaced claypans; merges into Qa.

Alluvial sand and silt

Map symbol. Qa.
Description. Unconsolidated fluvial sediments laid down in flood plains and in drainage depressions; merges into Qs and Qp.

DEFORMATION AND METAMORPHISM

Three major periods of deformation and metamorphism are evident in the area: D1, probably the Barramundi Orogeny, affecting the Lander Rock beds, but predating the Reynolds Range Group; D2, postdating the Reynolds Range Group but predating intrusion of Wabudali Granite and most other granite; and D3, the Alice Springs Orogeny, which deformed the Ngalia Basin succession. All three deformations appear to have resulted in north-south shortening, and structural trends are predominantly between east-west and northeast-southwest. Because of this, D1 structures cannot be readily distinguished from D2 structures in the Lander Rock beds.

D1 folds

The Lander Rock beds are tightly to isoclinally folded about subvertical east-west trending axial planes. The folds have wavelengths of around 1 km and gentle to steep plunges both to the east and to the west. These folds predate granite and also appear to predate the

Reynolds Range Group in the north, and hence are considered to be D1 in age. The regional schistosity in the Lander Rock beds is attributed to this deformation.

D2 folds

The only D2 fold identified is in the north, where the Reynolds Range Group is folded into a large upright to slightly overturned (to the south) isoclinal syncline which is more than 20 km long from west to east and 2 km across, plunging gently east in the west and more steeply west in the east. The cleavage in the Reynolds Range Group, and the main foliation in adjacent Lander Rock beds and gneissic granophyre, are parallel to the axial plane of this fold; i.e., the D1 cleavage, if present, is parallel to the D2 cleavage. The D2 syncline and associated cleavage are cut by, and hence predate emplacement of, the Wabudali Granite.

D3 folds

The Vaughan Springs Quartzite and overlying units of the Ngalia Basin succession form a series of D3 folds trending between east and east-northeast along the northern margin of the Ngalia Basin. These folds postdate the Devonian to lower Carboniferous Mount Eclipse Sandstone, and are attributed to the 400-300 Ma old Alice Springs Orogeny. They do not have an associated axial planar cleavage.

Faults

Some of the faults in the area are probably D3 structures, related to the Alice Springs Orogeny, especially those that affect the Ngalia Basin, but others may be older. The latter may include the numerous faults marked along parts of their length by ridge-forming veins of recrystallised quartz that is sheared, brecciated, and cut by quartz veinlets, suggestive of several phases of movement; rocks adjacent to these veins are commonly highly foliated to mylonitic. Most of the faults appear to be subvertical.

Metamorphism

The first two deformations recognised in the area were accompanied by regional metamorphism of low pressure/high temperature type. The Lander Rock beds were probably metamorphosed to mainly upper greenschist/lower amphibolite facies during D1, and, together with the Reynolds Range Group, to a similar or slightly lower grade during D2. Partial melting and development of migmatite assigned to the Lander Rock beds in the northwest is indicative of amphibolite facies or even granulite facies, which may be related to D1, or to subsequent granite-gabbro "hot-spots" (or even to a pre-D1 event, if further work shows that the migmatitic rocks are significantly older than, and basement to, the rest of the Lander Rock beds).

Most of the granites and mafic dykes in the area were intruded after the D2 folding of the Reynolds Range Group, but are metamorphosed: quartz in the granites is invariably highly deformed, and mafic dykes contain metamorphic sodic plagioclase and green amphibole indicative of upper greenschist or lower amphibolite facies. This late metamorphism may be related, at least in part, to the Alice Springs Orogeny, i.e., D3. The Vaughan Springs Quartzite, at the base of the Ngalia Basin sequence, may have been weakly metamorphosed (partly recrystallised to quartzite) at this time, but the overlying Mount Eclipse Sandstone does not appear to be metamorphosed.

The development of andalusite, muscovite, tourmaline, and garnet porphyroblasts, and also fibrolitic sillimanite, is restricted to pelitic metasediments within about a kilometre of granite intrusions, and is attributed to contact metamorphism related to the granite emplacement.

GEOLOGICAL HISTORY

The 1990 mapping in the Vaughan map sheet and adjoining sheets indicates the following sequence of major events (see also BMR, 1991).

- 1. Deposition of the Lander Rock beds. This thick unit of mainly turbiditic sedimentary rocks, but also some including cleaner and more siliceous clastics and both felsic and mafic volcanics, was probably laid down in deep water. It is lithologically similar to, and probably contiguous with, The Tanami Complex of The Granites-Tanami region to the northwest (Blake & others, 1979), and hence could be a correlative of the 1880 Ma-old Halls Creek Group of the east Kimberley and Warramunga Group of the Tennant Creek Inlier. Future U-Pb zircon dating of felsic volcanics in the west may resolve these uncertainties.
- 2. Intrusion of felsic magma. The Lander Rock beds were intruded by porphyritic granophye in the far north and possibly also by some granite (Pgf?) to the south.
- 3. Deformation and metamorphism. The Lander Rock beds were tightly folded and, together with granophyre in the north and possibly some granite to the south, were cleaved about upright east-west trending axial planes, and regionally metamorphosed, before being overlain unconformably by the Reynolds Range Group (e.g., Clarke & Powell, 1991). This tectonism (D1) may be related to the 1870 Ma-old Barramundi Orogeny of northern Australia.
- 4. Deposition of the Reynolds Range Group. After uplift associated with the Barramundi Orogeny and a period of erosion, the Reynolds Range Group was deposited in shallow water on a broad shelf or platform. Minor basaltic volcanism accompanied the sedimentation. The group is a probable correlative of the 1830-1800 Ma-old Hatches Creek Group, which unconformably overlies the Warramunga Group in the Davenport province of the Tennant Creek Inlier to the northeast (Blake & others, 1987), and hence part of a major sequence that once covered much of central Australia.
- 5. Deformation of the Reynolds Range Group. Sometime after deposition, but before emplacement of Wabudali Granite, the Reynolds Range Group was folded into a major east-west trending syncline and regionally metamorphosed to greenschist facies.
- 6. Granite emplacement. Large volumes of granitic magma were intruded into folded and cleaved Lander Rock beds and Reynolds Range Group to form the Wabudali Granite in the north and the coarsely porphyritic granite and other granites to the south.
- 7. Intrusion of mafic dykes. This event overlaps with event 6, as some mafic dykes postdate, whereas others predate, emplacement of porphyritic granite. The dykes may include correlatives of the 900 Ma-old Stuart Dyke Swarm exposed in the Arunta Block to the east.
- 8. Ngalia Basin sedimentation. The oldest formation in the Ngalia Basin, the Vaughan Springs Quartzite, is correlated with the ?850 Ma-old Heavitree

Quartzite of the Amadeus Basin to the south. Sedimentation continued intermittently until the Alice Springs Orogeny, the youngest formation preserved being the Devonian/Carboniferous Mount Eclipse Sandstone.

- 9. Alice Springs Orogeny. The Ngalia Basin sequence was folded and tilted during this 400-300 Ma old orogeny. At the same time the Arunta Block to the north was involved in faulting. In the eastern part of the area the Arunta Block appears to have been thrust southwards over the northern edge of the Ngalia Basin (e.g., Wells & Moss, 1983).
- 10. Denudation. Since the Alice Springs Orogeny the area has been part of a tectonically stable craton. Uplift associated with this orogeny was accompanied and followed by erosion. Denudation processes have continued with little interuption to the present day.

ECONOMIC GEOLOGY

The only known exploited mineral deposit in the mapped area is at Wilsons Find in the Mount Theo 1:250 000 Sheet area (Chilla 1:100 000 Sheet) just to the north of Vaughan (in the vicinity of GR 715685). Here wolframite with some malachite and chrysocolla occur with tourmaline in southeast-trending quartz greisen veins up to 2 m wide cutting granite (probably Wabudali Granite). The deposit was mined for tungsten during the 1940s, producing about 2 tonnes of concentrate (Stewart, 1976).

The Vaughan map sheet includes the western part of the Bigrlyi uranium deposit, discovered in 1973 (Wells & Moss, 1983; Fidler & others, 1990). The mineralisation consists of uraninite and carnotite lenses in Mount Eclipse Sandstone of the Ngalia Basin succession, near the northern margin of this basin.

For information on water supply, see Wells (1972) and Wells & Moss (1983).

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